Intelligent Transportation Systems

FHWA Local Evaluation

Pennsylvania Turnpike Commission's Advanced Traveler Information System (ATIS) Phase III Project

April 2006

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16. Abstract

In October 1998, the Pennsylvania Turnpike Commission (Commission) submitted a Partnership Agreement to the Federal Highway Administration (FHWA) for specific Intelligent Transportation Systems (ITS) activities, and to maximize the involvement of the Commonwealth and other project participants in the ITS program by the Transportation Equity Act of the 21st Century (TEA-21). Under this agreement for the Commissions Advanced Traveler Information System (ATIS) Phase III project, the following goal was sought:

Expand the Commissions statewide Advanced Traveler Information System to better inform motorists about traffic, weather and emergency conditions along the PA Turnpike through the use of highway advisory radio (HAR), variable message signs (VMS), closed circuit television (CCTV) cameras, roadway weather information systems (RWIS), vehicle rollover warning system, and traffic flow detection system (TFDS).

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1.   EXECUTIVE SUMMARY

The Pennsylvania Turnpike Commission (the Commission) owns and operates over 500 miles of tolled and non-toll roadways within the Commonwealth. This project concentrates on the mainline (I-76 and I-276) of the Turnpike which extends approximately 360 miles connecting Ohio to the west and New Jersey to the east and the Northeast Extension (I-476) of the Turnpike which extends 120 miles from the Mid-County Interchange in Montgomery County, PA to the Clarks Summit Interchange.

In 1998, the Pennsylvania Turnpike Commission, Pennsylvania Department of Transportation (PennDOT) and the Federal Highway Administration (FHWA) entered into Agreement No. 500013, which provided funds for the deployment of field devices and central software integration under Phase III (of VIII Phases) of the Turnpike's Intelligent Transportation System (ITS) Advanced Traveler Information System (ATIS) project.   Under this agreement, the federal funds were to be used to:

Expand the Commissions statewide Advanced Traveler Information System to better inform motorists about traffic, weather and emergency conditions along the PA Turnpike through the use of highway advisory radio (HAR), variable message signs (VMS), closed circuit television (CCTV) cameras, roadway weather information systems (RWIS), truck rollover warning system (TRWS) and, traffic flow detection system (TFDS).

Specifically, the Commission was looking to fill in the gaps of VMS, CCTV cameras and HAR signs throughout the Commissions Mainline and Northeast Extension roadways, add new RWIS, TFDS and TRWS to specified locations on the above mentioned roadways and to implement and integrate a Central Software to operate and control some of the Commissions' ITS subsystems.

As part of this agreement a Local Evaluation Report was to be created to review how well the project met the goals and objectives of the Agreement, provide the direct and indirect benefits of the project, as well as to discuss the technical and institutional issues that were encountered while completing the project.

Field Device/Central Software Deployment
The following field devices were constructed/integrated, under this project: 12 VMS, 8 CCTV Cameras, 21 HAR Signs, 4 RWIS Stations, 31 TFDS Locations, one (1) TRWS Installation and equipment integration utilizing the MIST® Central Operating System.

Lessons Learned
Although the project was a success, there were a number of challenges that needed to be resolved. These challenges are documented as "lessons learned" that will help in future ITS projects. The most notable lessons were as follows:

1. Have Good Communications With Your Consultants and Contractors
2. Get Key Staff Involved From the Beginning
3. Know Your Communication System Limits
4. Use Qualified Individuals for Post Design Services

5. Define Integration As Clear As Possible – Be Specific
6. Get Operations Personnel Involved Early in the Process
7. Follow the System Engineering Approach
8. Know Your Field Device Inventory

Project Benefits

This project provided a number of direct and indirect benefits to the Commission and its customers, including:

1. Increased Traffic and Incident Management Capabilities - The deployment of this system allows the Commission to provide continuous traffic and information services throughout a greater majority of its roadway network. From the Commissions' Traffic Operations Center, their operators are able to increase their customer service to the users of the roadway network by being able to provide information to motorists of the current travel conditions. The benefits realized in the reduction of incident delays, as well as secondary incidents as the Commission will be able to notify its customers of incident locations and to take alternative routes.

2. Provide Customers Greater Access to Traveler Information - All field deployments within this contract were designed and located to provide additional methods of collection and dissemination of data to Turnpike customers.   RWIS stations were placed at the most severe weather locations along the Turnpike to provide data back to the TOC. All VMS and HAR signs are located in advance of Turnpike interchanges, all CCTV cameras and TFDS's were located at interchanges with high average daily traffic (ADT). These additional VMS and HAR systems will add to the Turnpike's ability to disseminate information to their customers. The new systems deployed will be added information for the public to access through a future ITS website. This website will be linked to the current PTC website.

3. Immediate Reduction in Truck Rollovers - The installation of the Truck Rollover Warning System at the Breezewood Interchange has shown an immediate reduction in truck rollovers. Based on data from 21 months prior to the installation of the TRWS, there were a total of five (5) truck rollovers at that location of the interchange. The proceeding 21 months after the installation of the system noted a total of only one (1) incident. Also noted was a reduction in speed of trucks exiting the mainline.

Conclusion

This project represented the continuing efforts of the Commission's dedication to implementing and integrating the use of ITS technologies throughout their roadway network. Although the project was successfully deployed on time and within budget (with minor over/under runs), the design, integration and construction teams were faced with numerous challenges that required good coordination, and innovative thinking. The lessons learned from this project can be utilized with any ITS design and integration project. This project has provided the Commission with many direct and indirect benefits noted, and will continue to service the motoring public throughout the Commonwealth.

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2. INTRODUCTION

The Pennsylvania Turnpike Commission (the Commission) owns and operates over 500 miles of tolled and non-toll roadways with the Commonwealth. This project concentrates on the mainline (I-76 and I-276) of the Turnpike which extends approximately 360 miles connecting Ohio to the west and New Jersey to the east and the Northeast Extension (I-476) of the Turnpike which extends 120 miles from the Mid-County Interchange in Montgomery County, PA to the Clarks Summit Interchange.

In 1998 the Pennsylvania Turnpike Commission, PennDOT and the Federal Highway Administration (FHWA) entered into Agreement No. 500013, which provided funds for the deployment of field devices and central software integration under Phase III (of VIII Phases) of the Turnpike's Advanced Traveler Information System (ATIS) project. This Local Evaluation Report was completed to focus on technical and institutional issues encountered during this project, while providing an overview of the project and a summary of the design, construction and integration process.

3. PROJECT CONTRIBUTORS

The following organizations were instrumental to the overall success of this project:

Figure 1 – Project Contributors

Organization	Role	Main Point of Contact
PA Turnpike Commission	Project Leader	Lou Cortelazzi
PennDOT	ITS Partner	Mike Pack
FHWA	Project Oversight/Guidance	Jessie Young
DMJM Harris	Design/Construction Consultant	Edward Reagle / Daniel Corey
PB Farradyne	Integration Consultant	Larry Bankert/Pat McGowan
Penn State University	Research/Study Participant	Mike Patten
Carr & Duff	West Project Contractor	Ed Smith
Midasco Industries	East Project Contractor	Jim Gurganus

4. PROJECT DESCRIPTION

In October 1998, the Pennsylvania Turnpike Commission (Commission) submitted a Partnership Agreement to the Federal Highway Administration (FHWA) for specific Intelligent Transportation Systems (ITS) activities, and to maximize the involvement of the Commonwealth and other project participants in the ITS program by the Transportation Equity Act of the 21st Century (TEA-21). Under this agreement for the Commissions Advanced Traveler Information System (ATIS) Phase III project, the following goal was sought:

Expand the Commissions statewide Advanced Traveler Information System to better inform motorists about traffic, weather and emergency conditions along the PA Turnpike through the

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use of highway advisory radio (HAR), variable message signs (VMS), closed circuit television (CCTV) cameras, roadway weather information systems (RWIS), truck rollover warning system (TRWS), and traffic flow detection system (TFDS).

In 1998, the Turnpike Commission received $6.0M in funding through the TEA-21 ITS Integration component of the ITS Deployment Program. There was $525,000 added to this amount from funds not used in the previous year. Total FHWA contribution for this project was $6,525,000. Along with the Commission match, the overall project total was $8.2M. This funding was utilized to:

1. Fill in the gaps of VMS, CCTV cameras and HAR signs throughout the Commissions Mainline and Northeast Extension roadways.
2. Add new RWIS, TFDS and TRWS to specified locations on the above mentioned roadways.
3. Implement and integrate a Central System Software to operate and control the Commission's ITS subsystems.

The 1998 funding was broken down as follows:

PTC Contract No.	Engineer / Contractor / Integrator	Total Contract Amount / Bid Amount	Total Invoiced To Date / Final Amount	Tasks	Contract Status
98-039-RX10	DMJM Harris	$2,209,818.71	$2,030,452.76	Design Services / Construction Services	On-Going
98-039-RCEJ	Carr and Duff	$2,984,976.00	$2,902,133.61	West ITS Deployment	Completed
98-039-RCEK	Midasco, Inc	$1,661,700.00	$1,552,261.02	East ITS Deployment	Completed
98-039-RDLG	PB Farradyne	$485,053.45	$475,091.60	System Engineering for Software Deployment	Completed
98-039-RCAA	PB Farradyne	$1,102,694.14	$1,102,668.04	TOC Baseline Software Deployment	Completed
04-028-RC2Y	PB Farradyne	$146,543.09	$93,289.58	Web Page Development	On-Going
Total Project Cost to Date			**$8,155,896.61**		

Remaining project costs will be 100% Commission funded, which will amount to approximately $110,000 (less then 1% of the total project cost).

Within the Phase III device deployment, 12 VMS were added for operational needs, as defined by the Commission, eight (8) CCTV cameras were added at interchanges with high Average Daily Traffic (ADT), 21 HAR signs were used to fill in the gaps at the interchanges, four (4) RWIS were deployed at areas with the worst weather conditions, 31 TFDS were deployed at

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areas with high ADT and one (1) TRWS was deployed at an interchange that experienced high rollovers.

Prior to Phase III, the Commission's existing ITS field equipment included the following (**Refer to Figures 1 to 5**):

- Nine (9) Variable Message Signs (VMS)
  - M.P. 45.8 Eastbound (I-76)
  - M.P. 142.9 Eastbound (I-76)
  - M.P. 308.7 Eastbound (I-76)
  - M.P. 323.0 Eastbound (I-276)
  - M.P. 337.0 Westbound (I-276)
  - M.P. 59.7 Westbound (I-76)
  - M.P. A-23.7 Southbound (I-476)
  - (2) I-70 at the Breezewood Interchange

- Three (3) Closed Circuit Television (CCTV) Cameras
  - M.P. 324.0 Westbound - Valley Forge Interchange (I-276)
  - M.P. 333.5 Westbound - Plymouth Maintenance Facility (I-276)
  - M.P. 329 Eastbound – Eastern Regional Office (I-276)

- 74 Highway Advisory Radio Signs (HAR) at the following interchanges:
  - Cranberry (6)
  - Pittsburgh (5)
  - New Stanton (6)
  - Bedford (5)
  - Breezewood (5)
  - Carlisle (6)
  - Harrisburg West (4)
  - Morgantown (5)
  - Downingtown (4)
  - Valley Forge (4)
  - Norristown (2)
  - Mid-County (4)
  - Willow Grove (4)
  - Philadelphia (4)
  - Lansdale (4)
  - Pocono Valley (6)

- No Roadway Weather Information System (RWIS) Sites

- No Traffic Flow Detection Sites (TFDS)

- No Truck Rollover Warning Systems (TRWS)

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Figure 2 – Existing and Proposed Variable Message Signs

PENNSYLVANIA

Existing. (9) – PTC Phases 1 & 2

PTC Phase 3

Gateway IC (4)

M.P. 45.8 E.B.

M.P. 59.7 W.B.

Warrandale IC (4)

M.P. 81.7 W.B.

M.P. 104.9 E.B.

M.P. 142.9 E.B

M.P. 154.3 E.B. (1)

M.P. 175.9 W.B. (1)

On I-70 Breezewood IC (2)

M.P. A-23.7 S.B.

M.P. 323 E.B.

M.P. 337 W.B.

M.P. 308.7 E.B.

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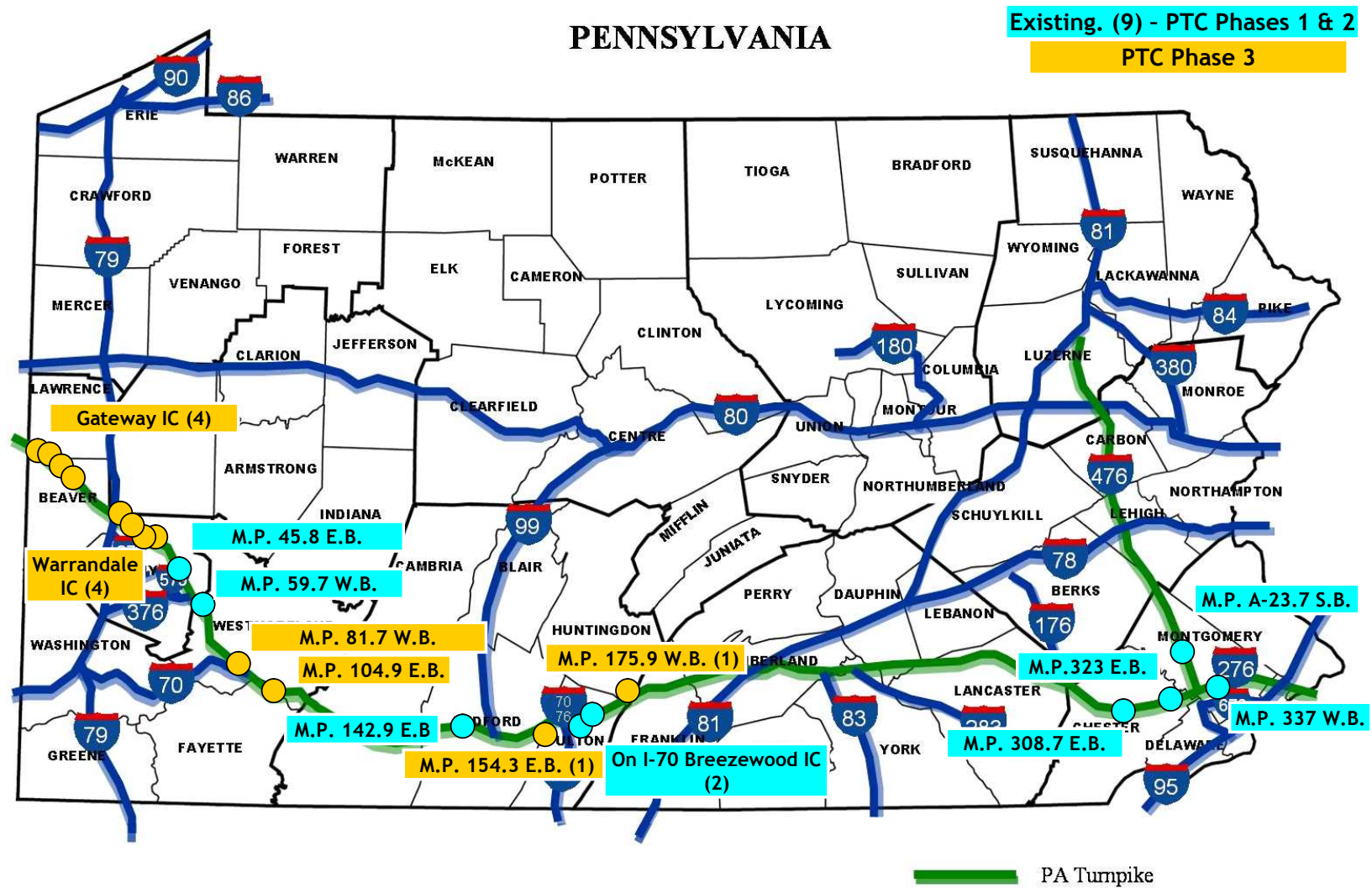
Figure 3 – Existing and Proposed Closed Circuit Television (CCTV) Cameras

PENNSYLVANIA

Existing (3) - PTC Phases 1 & 2

PTC Phase 3

Ohio Gateway (2)

Warrandale IC (2)

Pittsburgh IC (2)

New Stanton IC

Fort Washington IC

Plymouth Maintenance

Willow Grove

Valley Forge IC

ERO

Phila. IC

Breezewood IC (2)

PA Turnpike

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Figure 4 – Existing and Proposed Highway Advisory Radio (HAR) Signs
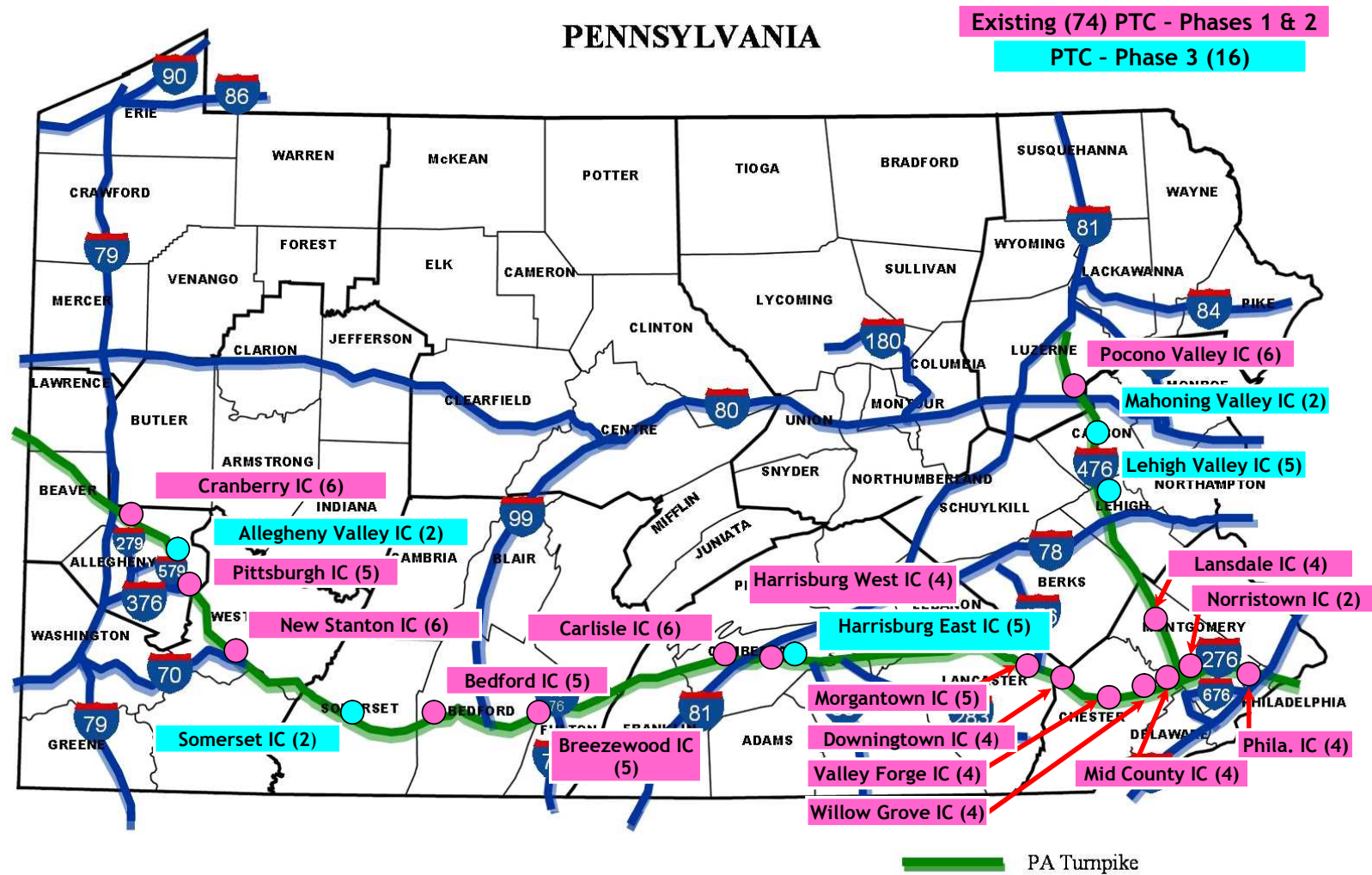
Figure 5 – Proposed Roadway Weather Information System (RWIS) Sites

PENNSYLVANIA

RWIS - PTC Phase 3

Hickory Run Service Plaza M.P. A - 86

Donegal/Somerset M.P. 99.5

West of Allegheny Tunnel M.P. 120.65

East of Breezewood IC M.P. 166

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Figure 6 – Proposed Traffic Flow Detection System (TFDS) and Truck Rollover Warning System (TRWS) Sites
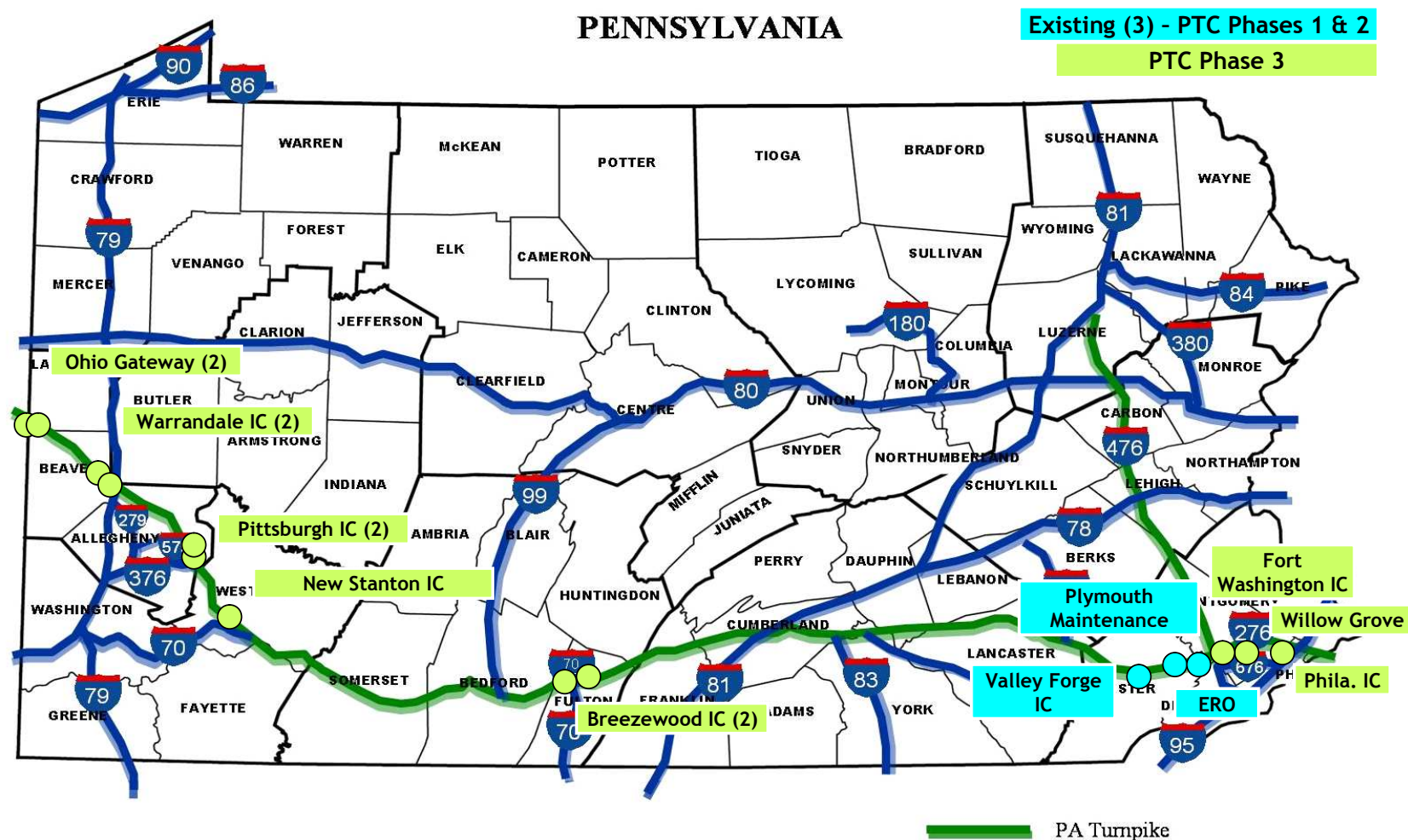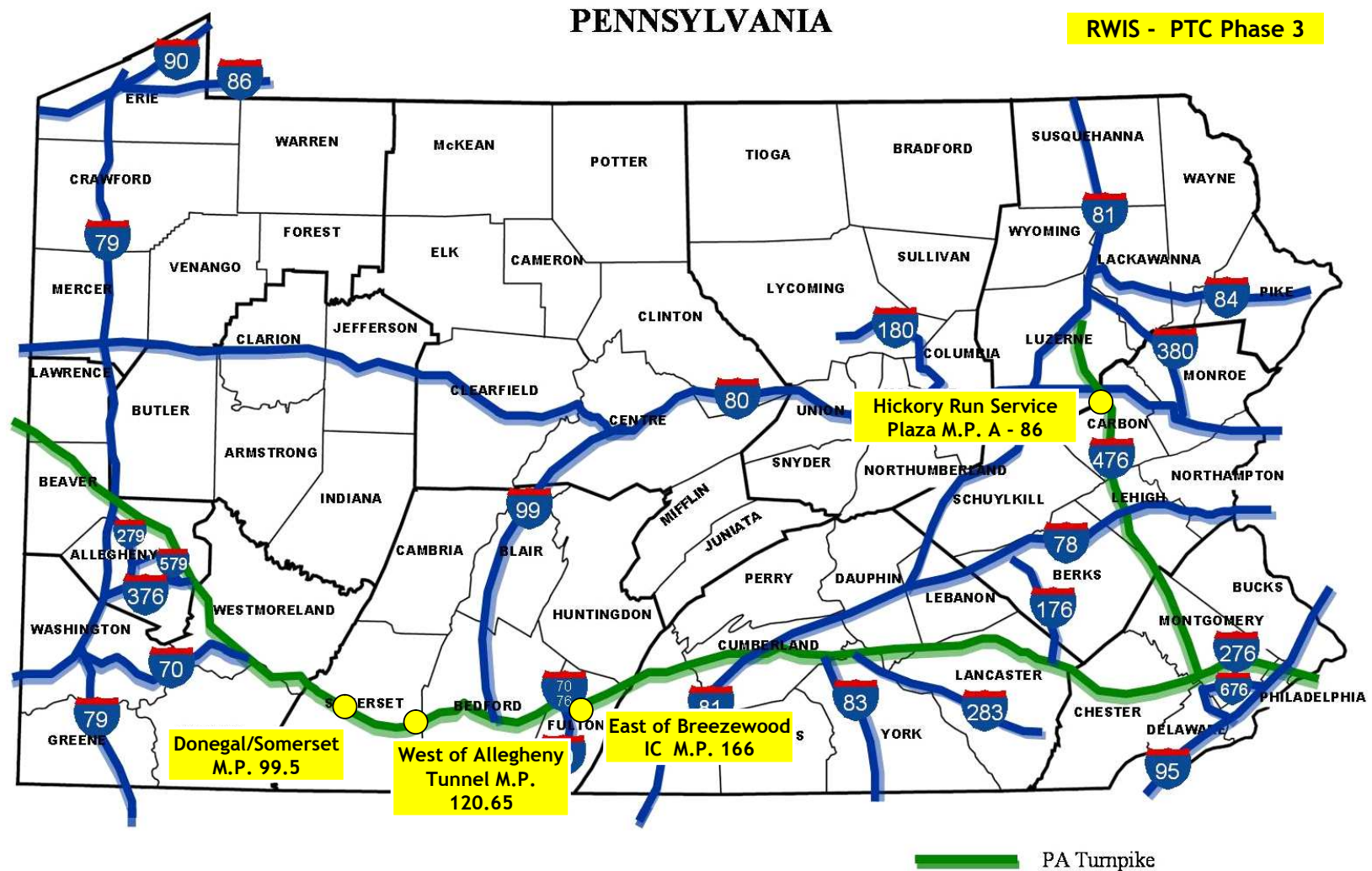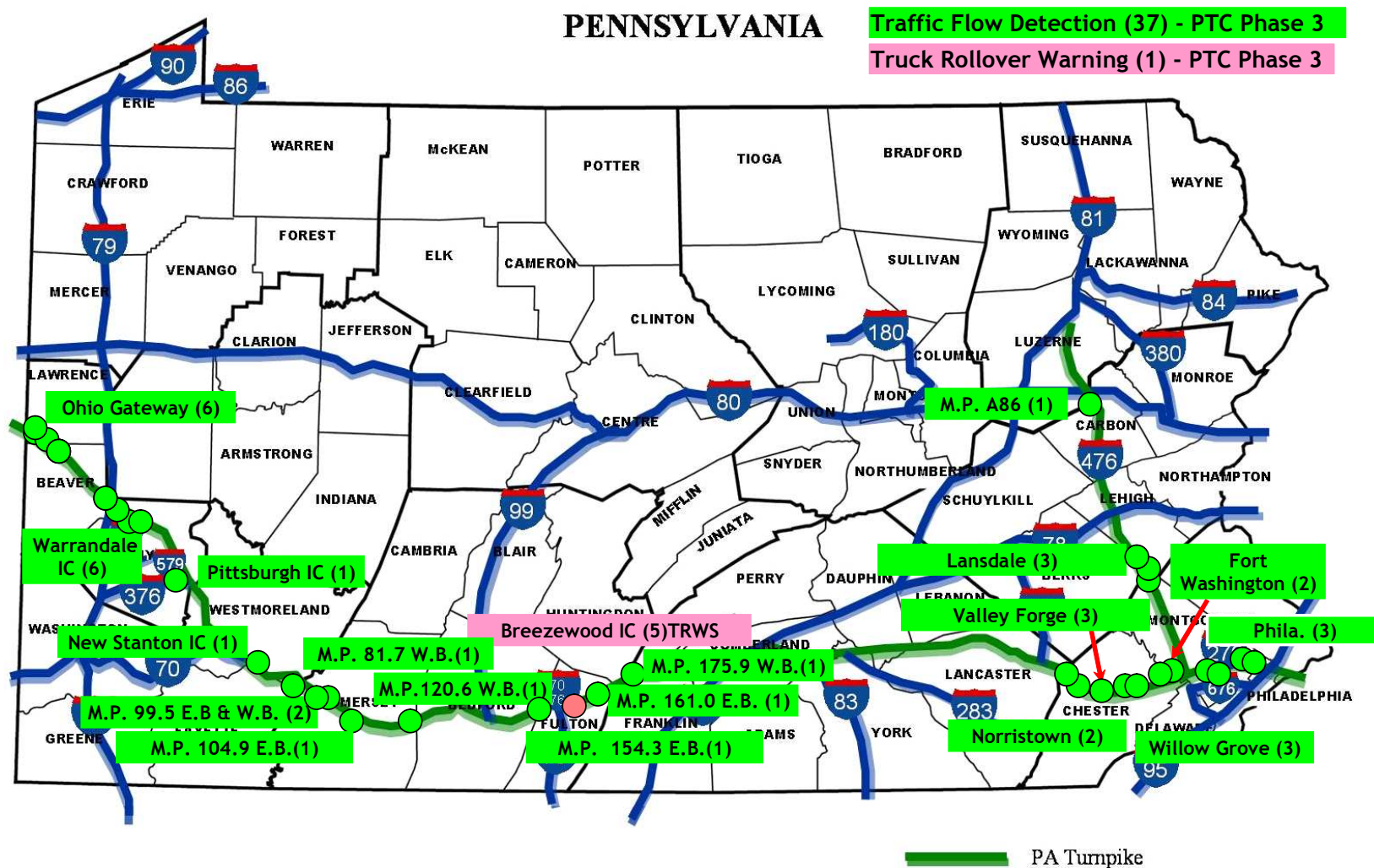
5. OVERALL PROJECT ASSESSMENT

This project represented the continuing efforts of the Pennsylvania Turnpike Commission's dedication to implementing and integrating the use of ITS technologies throughout their roadway network. Although the project was successfully deployed on time and within budget (with minor over/under runs), the design, integration and construction teams were faced with numerous challenges that required good coordination, innovative thinking and accommodating members to overcome. The lessons learned from this project can be utilized with <u>any</u> ITS design and integration project. This project has provided the Commission with many direct and indirect benefits noted, and will continue to service the motoring public throughout the Commonwealth.

6. LESSONS LEARNED

Through the creation of multiple contracts, as defined in Parts 4 and 5, there were various lessons learned and this evaluation will divide them into three (3) parts: Design, Construction and Software Integration. As defined in Sections 4 and 5, these projects followed the typical Design, Bid, Build and Request for Proposal (RFP) process. The project deployment consisted of new field devices and their eventual incorporation into a Central Software deployment. For this evaluation, the lessons learned will be both ones learned from the past and utilized on this project, as well as lessons learned and/or confirmed on this project. The lessons will include both positive and areas that needed improvement on this project. This section will denote the lesson and give a brief description of the lesson learned.

Design (Device Deployment)

6.1. *Know and Understand Your Needs*

At the beginning of any project, an internal needs analysis should be created. For this analysis, the entire organization should understand and agree to the needs developed. For this project, the Commission has many internal stakeholder groups including operations, engineering, information technologies (IT), maintenance and management. The analysis of needs included, at a minimum, the following internal needs:

- Operational Needs (Needs of the Commission)
- Design Needs
- Integration Needs

Separate from internal needs discussions, the following surveys were created and conducted by Penn State University to determine Customer needs:

Survey Name	Date Conducted
Test Plan: Motorist Survey	November 2000
Test Plan: Truck Driver Survey	November 2000
Test Plan: Motor Carrier Focus Groups	November 2000
Test Plan: Survey of Transportation System Operators	November 2000
Test Plan: Traffic Operations Effects of ATIS Deployment	November 2000

The Commissions perceived needs were compared with the needs of the customer, or end users. The commonality and the differences between needs of these two groups were critical to the design.

By determining the common needs from both the client (Commission) and the user (Turnpike Travelers), this project would help to fulfill the desires of both groups. It is highly encouraged that such understanding of internal and external needs are understood prior to the start of design of any ITS project.

6.2. *Have Good Communications with Design Team and Contractor*

With all projects, good communication is key to the projects success. With these projects there was very good communication among the Commission, its consultants, and contractors. Good communication reduced the likelihood of finger pointing and all participants being on the same page.

- Specifications – As device deployment specifications were being written by DMJM Harris for the final design, PB Farradyne was on-board as the software integrator. This was instrumental in being able to define and discuss the operations of the field devices with the software that would operate the system. This ensured that proper information exchange occurred between the Contractors and the integrators while providing a clear distinction in responsibilities.
- Coordination – There were good communications between the Commission and the consultants, between the consultants and the contractors and between the Commission and the contractors. Exchange of information (manufacturer's equipment, type, model number, and software version) prior to device installation was helpful to facilitate integration.

6.3. *Get Key Staff Involved*

At the start of every ITS contract, a core group of individuals (Information Technologies [IT], Operations, Traffic/ITS, Maintenance and State Police), representing the different disciplines should be selected as Key Members. Specific knowledgeable and decision making individuals from these groups should be present at every meeting to understand the projects current status, issues and future direction of the project. Include all IT disciplines at the meetings, including representatives from communications, software, database and system maintenance.

There was one specific area that could have been improved in this project. The Commission's various IT groups needed to be represented at the meetings and not just a general IT representative. During this project, not all of the Commissions IT groups attended project meetings. The general IT representative that did attend the meetings had limited capabilities to address concerns and action items during the project. Having all

the right people attend all meetings is key to the success of any project. In many cases throughout the project, smaller group meetings with IT personnel representing communications, software, field support and database were needed.

6.4. *Know Your Communication System Limits*

At the beginning of any project, a telecommunications assessment should be performed to fully understand the limits of the system in which you will be working. For this project, the communication system was determined. For other projects, it is important to identify all private (microwave backbone, WAN, or fiber) or public (Frame Relay Network, ATM, or POTS) communication networks.

Once the communications system has been identified, the amount of network expansion for future ITS projects or other agency projects need to be identified. For individual projects, the required bandwidth and time frame for the needs should be charted and tracked.

For this project there were two (2) issues with understanding the communication system and its limits. First, mis-communications between internal Commission stakeholders led to an overestimate of available bandwidth on the WAN. As the design was completed, it was later realized that the available system bandwidth was far less than what was originally identified.

The second issue was identifying the most appropriate communications equipment to use once knowing the actual bandwidth limitations. This was an opportunity to illustrate how good project relations can methodically address project "surprises". The design, based on the initial understanding of the bandwidth limitation, was to use MPEG 2 compression to convey video over the Commission's WAN. (At this time, MPEG 4 was a new technology and was not considered.) Therefore, a decision during construction to utilize MJPEG compression was made to convey the video images over the WAN, since it met the reduced bandwidth needs while providing satisfactory video images. This decision was made early enough in the contract that the manufacturing of the CODEC's had not begun. Both Contractors agreed to change to the MJPEG CODEC's and the manufacturer did not change the price.

6.5. *Keep the Design Simple*

The overall design philosophy should be to get the most efficient and effective system, as described by the functions required by the Commission. As an example in this project, the Commission requested a Truck Rollover Warning System, in which trucks entering a tight radius curve could be warned. The Commission was not looking for a weigh-in-motion (WIM) capabilities, headway measurements, height measurements or full vehicle classification data. System operations and maintenance determined that a simple system comprised of solid state switches and relays would be the best solution. In the end, the simple solution has been operational, without a flaw since its commissioning, whereas

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other similar systems within the State, with multiple functions, have been out of commission due to their intricate operations and maintenance requirements.

Another example of keeping the design simple was to start with a baseline software system. It was determined by the project team, that it was easier to start with something existing and then modifying it to the needs of the Commission. After a competitive selection process, the existing MIST® software platform was determined to have the most common functionalities required by the Commission and would be used as the baseline software. Modifications would then be made to the MIST® software to incorporate the customization required by the Commission.

6.6. *Bring Vendors to the Field*

Once technologies for field devices have been selected, it is recommended to have a technical expert from the manufacturer verify the design in the field. In the field, the vendor can verify the location and position of the equipment and provide recommendations that can optimize the system. The specifications can provide a provision that the manufacturer or a qualified representative must be in the field during installation and testing.

As an example on this project, a representative from the microwave detection system field verified the locations and setup of the units. In many cases, minor adjustments at the sites were recommended so that the equipment would perform as close to the product specification as possible, given the field conditions. These adjustments enhanced the performance of the field devices.

6.7. *Dedicated and Qualified Individuals Recommended for Post Design Services*

The field inspection and monitoring of the installation and integration of ITS projects requires skill sets different from those of roadway, bridge or typical electrical projects. The use of individuals that can dedicate the time to the project and know ITS equipment are recommended for post ITS design services.

From the experience on this project, it is recommended that all ITS contracts should use either ITS Engineers or qualified ITS inspectors for day-to-day inspection and testing procedures. The main responsibilities of the ITS field inspector and/or monitor should be, at a minimum, as listed in the following table:

Figure 7 – Construction Inspectors and Construction Monitors Responsibilities

Construction Inspectors Main Duties	Construction Monitors Main Duties
• Document the hours and tasks performed by the Contractors personnel at each site location. • Document the quantity of equipment and materials being installed in the	• Inspect and document all Stored Materials to verify that the Contractor is following proper procedures. • Witness field device commissioning. • Verify that the Contractor is installing

field on a daily basis by the Contractor. • Verify that the Contractor is installing the equipment correctly, as per the contract documents and as per national and local building codes. This also includes the ability to answer the Contractor installation questions, concerns or changes. • Review all monthly invoices and Change Orders submitted by the Contractor. • Track Punch List items	the equipment correctly, as per the contract documents and as per national and local building codes. This also includes the ability to answer the Contractor installation questions, concerns or changes. • Provide oversight and assist in Stand Alone, System and Operational Acceptance Testing procedures. • Track Punch List items

Under the two (2) construction contracts in this project, the Commission provided construction inspection for the East Contract and the design consultant, DMJM Harris, provided construction services for submittal reviews and testing oversight. Under the West Contract, DMJM Harris provided both the full time inspection staff and construction services. Due to this approach, the following differences between the two construction contracts were as noted:

- Installation concerns and field changes were addressed and solved more efficiently in the field in the West contract. This led to shorter construction delays.
- Day-to-day status of the project was better documented in the West contract, as the full time inspector was involved in every aspect of construction. Since the East contract inspector was not full-time, the Contractors progress could not be as easily tracked and reviewed.

6.8. ITS Projects Should Have an ITS Contractor, ITS Integrator or ITS Consultant as the Prime Contractor

An ITS project should be separated from a larger contract and bid separately, since the qualifications needed to design/install are different from most heavy construction contracts. The Commission found that in previous contracts, in which ITS equipment was installed by a General Contractor, there were communication issues between he Commission and Contractor. The General Contractor would hire an electrical contractor, who would hire an ITS Contractor/Integrator, who hired a supplier/vendor. This hierarchy of organizations made it very difficult to control/monitor the construction activities.

Learning form their past experiences, the Commission decided to utilize this approach for their future ITS projects, as it provided a positive result during this contract.

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6.9.   *Account for All Spare Parts*

All contracts should include spare parts for all subsystems within the contract, including but not limited to: CCTV, VMS, HAR, RWIS and communication subsystems. These spare parts should be tracked during the installation/maintenance portion of the contract, so that at the end of the contract, required spare equipment is stored and in good condition. On many projects, spare equipment is used during maintenance, if a part is broken or malfunctioning. The Commission needs to verify that the spare equipment part that has been used is either restored or replaced with a working part, and that part is inventoried and accessible to the Commission.

In this project, the status of the spare equipment was not known until the end of the maintenance period, when the Contractor provided the equipment to the Commission. It is recommended that the history of the spare equipment be logged and this documentation should be provided to the agency at regular intervals or during status meetings.

Integration (Software Design and Deployment)

6.10. *Define Integration and Control the Project Limits*

This project experienced two project bid processes. The first contract package was prepared to include VMS, CCTV cameras, RWIS, TFDS, and TRWS field devices and central software to control the TFDS and VMS. The contract also included a software provision for the truck rollover system that required that the processing of the vehicle speed detection inputs, and then perform a series of computations and algorithms to generate a series of outputs to warn the truck drivers of dangerous operations. Finally, as part of the first contract was the location of field devices along 300 miles of the Pennsylvania Turnpike.

The software requirements and the large project area resulted in extremely high bid from the contractors. The bids could not be justified resulting in the rejection of the bids and no selection.

In the second contract letting, the integration efforts of the field device deployment were better defined. The TRWS functional requirements were re-evaluated and a less complex system with no software integration was designed. A more simple system consisting of relays and switches was utilized to perform the basic functions required by the Commission. In addition, two (2) field installation contracts were prepared, based on geography to provide better competition and economies with more localized contracts. Also, the contract required use of the Commission's existing wide area network (WAN) to convey data from the field devices to the Commission's operations center. The device deployment contracts had a stipulation added that the Acceptance Testing would be administered by the Design and Integration consultants (DMJM Harris and PB Farradyne), respectively. In addition to the two (2) field device contract, another separate contract was awarded for strictly software integration.

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The results of the second set of bids was much favorable and within 1% of the Engineers Estimate. So, this example proves that better defining the projects integration and controlling the projects limits resulted in a better bid and a clearer understanding of the project by the Contractors.

6.11. *Get Operations Personnel Involved Early in the Process*

One of the main areas of improvement realized from this project is to get operations personnel involved in the process from the start. The day to day operators of the system, the end-user, will embrace the new system much quicker and without reservation if they have been apart of the entire process. This involvement would provide them with a sense of ownership of the system, as well as a clear understanding of the limitation and expectations of the system. When it comes time to use the system, the operators already understand the systems capabilities and limitations and will not be disappointed in the system.

In this contract, the operators were not made key team members until further on in the project. Operator suggestions and the resulting changes to the system were minor, but they provided the user a sense of ownership of the system. The Operators made suggestions in regards to screen appearance, icons, and map appearance, which helped to enhance the project. Bringing operations personnel on at the beginning would have resulted in a more efficient design and customization of the integration software.

6.12. *Follow the System Engineering Approach*

All projects should follow the FHWA's System Engineering approach philosophy for all projects because it establishes the foundation for the project and helps to prevent scope creep.

For the integration project, a Concept of Operations, as well as high-level and detailed design requirements were created early on in the process and were agreed to by all individuals. This helped to keep the team focus on the requirements and not change the direction of the project. From this understanding, detailed design, implementation, integration and testing, system verification and system acceptance were performed with few issues. Operations and maintenance of the system then completed the process, as operations still successfully continues today.

6.13. *Know Your Inventory*

At the beginning of the software integration project, or even before the contract goes out as a Request for Proposal, the owner should have a list of all equipment that is owned, operated and maintained by the agency. This list should include the following information about each piece of equipment:

1. Manufacturer/Make/Model
2. Communications Protocols

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3. Installation and Test Dates
4. Warranty Period(s)
5. Spare Parts Inventory
6. Software Version (May not be the same version for the same manufacturer)
7. NTCIP Compliance (Do old devices meet current standards)

At the beginning of this project, the Commission did not have all of this information. When the field devices were integrated into the software, there were compatibility issues and multiple modules required to integrate similar equipment. During this project, it was discovered that different versions/releases of similar equipment were not compatible with NTCIP standards and required multiple modules to integrate the equipment. This resulted in delays in the completion of the software.

Therefore, creating or maintaining an inventory list of all hardware and software devices will help better define the work required by the integrator, resulting in a clearer understanding of the components of the system and system integration and a tighter scope and bid price.

6.14. *Provide Hands-On Training*

Provide the operators with both simulation and hands on training, and not just simulation training. Under simulation modes of training, many times the ideal conditions are set, and do not give an accurate depiction of operations. The operators need to get an understanding of how the system will operate under actual conditions. As an example, if communications to field devices is by internal WAN and dial-up leased line telephone service, there will be a difference in equipment response time.

The training should also include members of the system support staff, so if errors occur during training, the system staff can explain the reasoning behind the error, what to do incase of the error, and how to fix the error if it occurs. This understanding of the system should not be up to the operator to determine on their own.

6.15. *Provide a Burn-In Period Prior To Operational Testing*

It was noted that a burn-in period should coincide with the hand-on training. During this time, the operators will use the system under everyday working conditions. This will provide an opportunity for the field equipment to be used and stressed. Normally, it is during this initial period of the "U-Curve" that the equipment will experience failures. It would be more advantageous if minor equipment failures occurred during this hands-on period, when corrections can be easily made, than during the operational testing period, where there should be no failures.

7. SYSTEM BENEFITS

This project has significantly extended the ITS system throughout the mainline and northeast extension of the Pennsylvania Turnpike. The project increased the number of CCTV cameras by 400%, increased the number of VMS by 33%, increased the HAR signs by 20% and introduced new RWIS, TFDS and TRWS subsystems. The project also incorporated the TFDS and VMS subsystems under single operating software at the Traffic Operations Center (TOC). Overall, the system has already provided a number of direct and indirect benefits, as listed below:

7.1. *Increased Traffic and Incident Management Capabilities*

The deployment of this system allows the Commission to provide continuous traffic and information services throughout a greater majority of its roadway network. From the Commissions' Traffic Operations Center, their operators are able to increase their customer service to the users of the roadway network by being able to provide information to motorists of the current travel conditions. The benefits realized in the reduction of incident delays, as well as secondary incidents as the Commission will be able to notify its customers of incident locations and to take alternative routes. This will also allow for easier emergency vehicle access for incident response. The additional VMS installed will also increase the coverage area for the postings of Amber Alerts.

### 7.2. *Provide Customers Greater Access to Traveler Information*

All field deployments within this contract were designed and located to provide additional methods of data collection and the dissemination of information to Turnpike customers. RWIS stations were placed at the most severe weather locations along the Turnpike to provide data back to the TOC. All VMS and HAR signs are located in advance of Turnpike interchanges, all CCTV cameras and TFDS's were located at interchanges with high average daily traffic (ADT). This information can be disseminated to the Turnpikes customers via their VMS and HAR systems, as well as on their website, www.paturnpike.com.

7.3. *Immediate Reduction in Truck Rollovers*

The installation of the Truck Rollover Warning System, at the Breezewood Interchange, has shown an immediate reduction in truck rollovers. The system is based on a two phase notification approach utilizing Microwave detectors, static signs with flashers and blank out message signs. The system works as follows (refer to **Figure 6**):

- Overhead forward facing microwave detectors identify all trucks that have just exited the mainline of the turnpike. When the microwave sensors identify a truck, the flashers are activated.
-

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Figure 8 – Truck Rollover Warning System
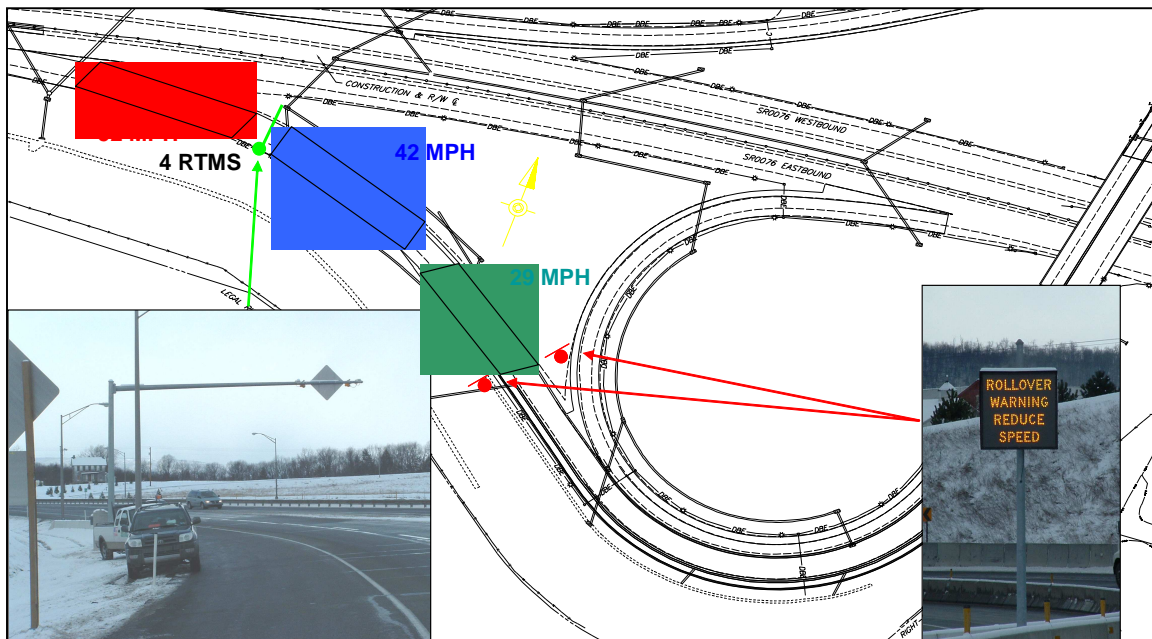
- After the truck passes under the static sign with the flashers, within approximately 70-feet, a second set of microwave detectors identifies two characteristics (classification and speed).
- If the classifier determines the vehicle is a truck AND is traveling OVER a set speed (set at 35 M.P.H.), two (2) blank out message boards reading "ROLLOVER WARNING, REDUCE SPEED" are activated prior to the tight curve, signed for 25 M.P.H.
- If the classifier determines the vehicle is a truck AND is traveling UNDER a set speed (set at 35 M.P.H.), two (2) blank out message boards reading "ROLLOVER WARNING, REDUCE SPEED" are not activated prior to the tight curve, signed for 25 M.P.H.
- If the classifier determines the vehicle is a not a truck, two (2) blank out message boards reading "ROLLOVER WARNING, REDUCE SPEED" are not activated prior to the tight curve, signed for 25 M.P.H.

The immediate affects of the system are two (2) fold:

1. Reduction of truck rollovers – Based on data from 21 months prior to the installation of the TRWS, there were a total of 5 truck rollovers at that location of the interchange. The proceeding 21 months after the installation of the system noted a total of only one (1) incident. This one incident was caused by a motorist, traveling in a car, making a sudden uncontrollable move in their automobile. A truck, near the car, was forced to make a reactive move that caused it to rollover.

2. Reduction in speed – Speed measurements taken after the installation of system, showed that trucks entering the off-ramp demonstrated the following:
- ➢ Mainline speed – 65 M.P.H.
- ➢ Truck Speed Approaching 1st set of Detectors – 52 M.P.H.
- ➢ Truck Speed Approaching 2nd set of Detectors – 42 M.P.H.
- ➢ Truck Speed Approaching Blank-out Signs – 29 M.P.H.

7.4. *Economic and Environmental Benefits*

The economic benefits that are anticipated from the deployment of these additional devices have been identified based on similar ITS deployments around the country. The first economic benefit is the savings associated with the reduction of the duration of delays. The deployment of theses types of systems result in private and commercial travelers saving time due to fewer delays. While a quantitative analysis of the benefits was not completed for this project, it has been shown by previous analyses that the combined direct and indirect economic benefits of similar systems can potentially be several million dollars a year.

The environmental benefits associated with expansion of the Commission's system are based on the reduction of emissions from vehicular travel caught in delays from extended time in incidents. This reduction in emissions provides a quality of life benefit for those who live in and around congested urban areas.

8. CONCLUSION

This project represented the continuing efforts of the Commission's dedication to implementing and integrating the use of ITS technologies throughout their roadway network. Although the project was successfully deployed on time and within budget (with minor over/under runs), the design, integration and construction teams were faced with numerous challenges that required good coordination, innovative thinking and accommodating members to overcome. The lessons learned from this project can be utilized with any ITS design and integration project. This project has provided the Commission with the many direct and indirect benefits noted, and will continue to service the motoring public throughout the Commonwealth.

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